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RESEARCH ARTICLE

Habits Over Routines: Remarks on Control Room Practices and Control Room Studies

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Abstract. The evolution of computer tools has had profound impacts on many aspects of control rooms and control room studies. In this paper, we discuss some key assumptions underpinning these studies based on a new case of the electricity distribution control rooms, where the reliability of the electricity infrastructure is managed by a combination of planning and real-time maintenance. Some of these practices have changed remarkably little over the past decades – partially because they have been considered to have been 'digitalized' since the 1950s and have continued to amass digital solutions from different periods. Hence, the gradual transformation of control room work demands nuanced attention, both conceptual and empirical. To outline a framework for this work, we provide a conceptualization of organizational routines, habits, and reflectivity and synthesize existing CSCW and control room literature. We then present an empirical study that demonstrates our concepts and shows how they can be applied to study cooperative work. By addressing these aims the paper complements, and advances, the important topics recognized in this special theme issue and hence develops new research openings in CSCW. We address the necessity to avoid implicit determinism when analyzing new digital support tools and suggest focusing on how working habits mediate social changes, distribution, and decentralization in representing the power distribution in control rooms.

Keywords: Electricity distribution control rooms, Habits, Sensemaking, Digitalization, Marketization

1 Introduction

The objective of this paper is to produce research concepts for the study of control rooms that have highly programmed working routines but encounter constantly changing conditions and a myriad of technological changes. The design, implementation, and use of technical systems, and people working cooperatively, are themes intrinsically connected to the research on control rooms. These interconnections have been studied extensively and a control room forms an established research site in various fields; ranging from workplace studies and

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ethnomethodological scholarship (Heath and Luff, 2000; Gobo, 2008; Suchman, 2011) to urban and geographical studies (Anderson and Gordon, 2017; Luque-Ayala and Marvin, 2016) and organizational studies over several decades (Roe and Schulman, 2008, 2018; de Bruijne and van Eeten, 2007; Schulman and Roe, 2007; Schulman et al., 2004).

The Computer Supported Cooperative Work (CSCW) journal has dedicated several studies (Pettersson et al., 2004; Purohit et al., 2014; Almklov et al., 2020) and systematic reviews to the control rooms literature within CSCW (Blomberg and Karasti, 2013; Randall et al., 2021). The core theme of social change and new working methods and devices, such as digital support tools (Letondal et al., 2013; Panagiotou et al., 2016) and social media platforms (Purohit et al., 2014), have underpinned many commentaries, including this special theme issue. This shared theme puts the scholarly discourse into a dilemma: the research field is dedicated to the study of everyday work vis-á-vis its immediate contexts (Østerlie et al., 2012; Almklov et al., 2014), yet technologies developed outside of the control room cause changes in social working practices inside these rooms. The call for papers is a case in point: it places together new digital technologies with decentralization, distribution, and fragmentation, implicitly suggesting that there is an ongoing shift in all these directions, potentially amplified by technological revolutions in the workplace.

This dilemma is certainly visible in our field of infrastructure studies. We will use two popular and appealing diagnoses as examples to root our concept on everyday control room work: starting from the earlier discourse of marketization of infrastructure and proceeding to more recent visions of merging electricity infrastructure with information infrastructure, or "digitalization" as it is often called (International Energy Agency, 2022).

Graham and Marvin (2001) linked systems like telecommunications, roads, energy, and waste management with cities and urban life. Urban planners, engineers, and national and regional policymakers shared a "modern infrastructural ideal" that drew on rational planning and emphasized universal infrastructure provision, uniform service pricing, and the role of infrastructures in increasing welfare.

Such an almost ubiquitous rationale for universal infrastructure provision in industrialized countries started to be critiqued in the 1960s. Emerging economic theories addressed infrastructural issues – e.g., breakdowns and urban sprawl – by creating more room for commercial interests in infrastructure provision. Infrastructures everywhere are converging towards more competitive liberalized provision, which Graham and Marvin (2001) coined as "splintering urbanism" due to its fragmenting of previously universal public infrastructures and consumers.

The "splintering urbanism" thesis hence constitutes one grand diagnosis of political economies and their impacts on infrastructure provision. A new and closely related narrative emerged several years ago in the field of electricity grids. Slayton

(2013, p. 449) describes it as "digital utopianism": "the belief that digital information and communications technologies will revolutionize human affairs for the better". Electric grids are "rewired" with information infrastructures, creating "a system designed to enable power producers, transmission operators, distribution systems, and consumers to exchange information seamlessly" (p. 449). The International Energy Agency (2022, n.d.) and its visions of "digitalisation" and "digitalised energy systems in the future" are familiar from this perspective, with their focus on connectivity and instant information exchange, bringing forth a market-based conclusion with digital applications giving abilities to "identify who needs energy, deliver it at the right time, in the right place and at the lowest cost."

We contend that to avoid implicit technological determinism, these changes should be posed as problems for nuanced empirical inquiry. In our field of infrastructure studies, it is plausible to assume that certain aspects of control rooms have been changed by digital tools and associated new market-based relationships. Yet some control room practices have changed remarkably little, partially because they have been 'digitalized' since the 1950s (Cohn, 2015) and because control rooms have continued to amass digital solutions from different periods. To grasp the effects of new technologies on (the transformation of) control room work thus demands nuanced empirical attention to cooperative interaction in situ.

Our paper zooms into one such site: the electricity distribution control room, where the reliability of the electricity infrastructure is managed by a combination of planning and real-time maintenance. The paper builds both conceptually and empirically: we provide a synthesis of existing CSCW and control room literature, but also present an empirical study that demonstrates our concepts in action and shows how they can be applied to study cooperative work.

We start off by reviewing cornerstone concepts, namely habits, reflectivity, and organizational and working routines. This is followed by literature that was collected from the archives of CSCW on control rooms but extended to related journals in human geography, organizations, and information systems to represent the interdisciplinary field. We then introduce the methods and materials before moving on to analyze the electricity distribution control room. The key results – social change, routines, and sensemaking – are presented in related subsections. The final part concludes with future directions for CSCW research on control rooms based on our findings.

2 Review and conceptual perspective

2.1 The concepts of habit, routine, and reflection

To frame the main issues of the paper, conceptual work is needed. Practices, habits, routines, reflectivity, and reflexivity are popularly used in control room studies albeit not always well-elaborated as research concepts. Moreover, while some of the concepts

are used interchangeably, we discuss their differences and point out different methodologies they unfold to add rigor to conceptual frameworks for control room studies.

The shared starting point of the CSCW literature on control rooms is the study of working practices. Practices, drawing from ethnomethodology (see review in Silvast and Virtanen, 2021), are designated generously as everything that goes on in everyday human work in its accomplishment, rather than its rational accounts only (Østerlie et al., 2012; Almklov et al., 2014). We acknowledge the need to study practices, but instead of the phenomenology-inspired ethnomethodology and the concept of practice, our research work is rooted in pragmatist philosophy and in its core concept of habit.[1]

Habits do not mean routines, mannerisms, or action that is repeated mechanically (Kilpinen, 2000, p. 57). Rather, habits are the most continuous and general aspect of action; all action is already ongoing and always to some extent habitual. Habits also direct action which becomes apparent whenever habitual action is interrupted. A habit is a belief that is effective as long as it is not interrupted by a "doubt", which in turn can lead to the formation of new habits (Kilpinen, 2000, pp. 217–28). This idea is called the circularity of action, and to pragmatists, *reflectivity* is an outcome of doubt in this circle; habitual action is interrupted and reflecting brings one back to the state of belief.[2] Yet reflection also takes place in action, not before or outside it, and as habits are generalizations from previous experiences, they become a resource for reflective phases of action, such as decision-making. In this context, then, doing and sensemaking, or creativity and habituality in pragmatist terms (Kilpinen, 1998), cannot be fully separated.

[1] When speaking about pragmatism and habits, we are particularly indebted to the research of the late Finnish sociologist Erkki Kilpinen. Kilpinen (2000) outlined American pragmatism as a parallel classic tradition in sociology, which was largely neglected by Talcott Parsons, but vindicated throughout the last decades of the 20th century (Camic, 1986; Robertson and Turner, 1989). The tradition covers several classic pragmatist philosophers, but the concept of habit is particularly based on the work of Charles Sanders Peirce, William James, and John Dewey. The notion of habit lies at the heart of pragmatism's approach to action. Habits are elementary forms of any action which involves also (cognitive) intentionality – and thus also creative action – as part of habitual action processes (Kilpinen, 2016, 2009). These action processes are not individual but develop and occur as shared and collective. We develop such a notion of habit alongside our analysis of control room practices as not mere routinization of single intentional acts nor non-intentional repetition either but as habitual chains of action during which also cognitive reflection takes place. This pragmatism is not merely a metatheoretical stance but opens up several ways to conduct empirical research also beyond the scope of the present paper. For instance, the connections between collective habits and frameworks for "communities of practice" applied in CSCW (Su et al., 2012; Sandusky, 2003; Büscher et al., 2001) would merit further attention. Future studies in the CSCW area could ask whether and if so, how, collective workplace habits also allow people to share relevant knowledge and experience in their communities of practice.

[2] This meaning of 'reflectivity' is complementary but potentially different from the ethnomethodologically-inspired concept of 'reflexivity'. Whereas pragmatism does not separate creativity and habits per se, ethnomethodologists tend to treat doing and sensemaking as analytically separable. Ethnomethodologists approach social orders as constantly emerging in situational interactions through shared sensemaking. In this framework, the concept of *reflexivity* refers to partaking actors' sensemaking of (the production of) the social structuredness of the setting at hand; the actors involved become "reflexive" of both making sense of the social setting and the ongoing production of that setting (Heritage, 1984).

The rich tradition of CSCW has been particularly interested in material tools and working practices in difficult settings such as control rooms. It thus offers several qualifications which can be further elaborated from a pragmatist point of view. First, adopting pragmatism does not need to imply a focus on human actions only. Reflection often arises from interacting with materiality such as infrastructures, technologies, tools, and devices, from visual models to checklists, and so forth (Østerlie et al., 2012; Almklov et al., 2014; Niemimaa, 2016). Another way around, material arrangements can be – and in fact, in control room settings are – relied on to return to habits in a situation of doubt.

Secondly, and relatedly, the CSCW tradition has developed an elaborate concept of working routines. The classic concept of organizational routines (March and Simon, 1958) designates them as repetitive actions by multiple actors. In this established conceptualization, routines emerge from repeated experiences – just like pragmatism tells us – but also require minimal effort from the actor.

> When a stimulus is of a kind that has been experienced repeatedly in the past, the response will ordinarily be highly routinized. The stimulus will evoke, with a minimum of problem-solving or other computational activity, a well-structured definition of the situation that will include a repertory of response programs and programs for selecting an appropriate specific response from the repertory. (March and Simon, 1958, p. 140.)

This classic approach likened organizational routines to individual habits but understood habits to "require no thought; they are automatic" (Feldman and Pentland, 2003, p. 97). We contend that this is a misrepresentation of both habits and routines from a pragmatist point of view. Drawing from Almklov et al. (2014), we understand *routines* as formalized work practices that have been inscribed in a material form, such as documents describing work tasks, flow diagrams, and organizational charts. Routines are typically contained in formal procedures and rules – as we show below – but this is not the only essential part of the analysis of routines. As Feldman and Pentland (2003) show, routines are actions, not just their description. Their work further distinguishes two kinds of routines: *ostensive routines* are contained in guides and accounts, whereas *performative routines* denote specific actions by particular people when bringing the routines to life.

This two-part definition of routines is developed from Science and Technology Studies (STS) and is also directly compatible with our interest in pragmatism. Action is formed of habits and some of these habits are inscribed in working routines, which can themselves be written to protocols, standards, checklists, and so forth. Nevertheless, these routines need to be brought to life by the control room workers to be effective. They do this, particularly in problematic situations where habits need to be resumed. This resumption of habits can rely on

cognitive-reflective decision-making but is typically mediated by technologies, such as phone calls, computer models, automation software, or a whole Information Infrastructure. It is this interplay of habits, infrastructure, technologies, and work that we drill into via control rooms next.

2.2 Summarizing previous perspectives from computer-supported collaborative work

CSCW literature on control rooms shows several themes that speak to our point of view of ongoing action as developed within pragmatism. We summarize and comment on a selected aspect of this work, but do not aim at a systematic review of previous studies within the space we have. That said, across the reviewed body of literature, there are four common messages that emerge each of which we now discuss in turn.

First, the control rooms examined lie at the crossroads: connecting different organizations and their staff, standards, and activities (de Bruijne and van Eeten, 2007). In doing so, and internally, they furthermore bring together routines, habits, and material artifacts: including informal and formal systems of accountability (Almklov et al., 2020) and informal and formal response communities to crisis (Purohit et al., 2014). All these practices need to be merged in and through the control room practices.

Second, the clear role of technical and material tools in supporting working practices comes across in several of the studies (Østerlie et al., 2012; Almklov et al., 2014; Niemimaa, 2016). The local social order in control rooms and the systems that they coordinate is performed by computer tools and artifacts (Whalen, 1995), and the control room's physical objects act both as mental representations and interactive artifacts to wider systems (Letondal et al., 2013). While new digital media has received attention in this context, some of these tools supporting coordination are decisively firm and established, such as the radiophones that enact the institutional order in air traffic management (Juhlin and Weilenmann, 2005) or large paper maps that co-exist with advanced digitalized maps in emergency dispatch (Pettersson et al., 2004).

Third, this focus on tools is inherent to many of these studies – and we would argue, joins infrastructure studies and Science and Technology Studies (STS) more generally, including participatory design and viewpoints on technology-in-use (Hartswood et al., 2002). But especially Monteiro et al. (2013) have highlighted how tools in cooperative work are often not just any situated technologies, but technologies that need to adapt to distinct non-local constraints. Naming these tools Information Infrastructure, the study focuses on the structuring impacts of standardization and embeddedness in other unrelated technologies to point out what digital tools are like.

The fourth message takes a different direction yet follows from the marked focus on the control room tools both formally and informally. Many control

room studies put considerable stress on studying the events happening in control rooms, often as they manifest in the tools used such as computer screens. One study on traffic control even contrasts events directly with 'non-events' that they define as routine occurrences (Anderson and Gordon, 2017). This is at odds with our definition of routines as performative (Feldman and Pentland, 2003) and equally 'event-like' as any form of action. Others lay considerable stress on control room 'incidents' that arise and are recorded in information systems (Luff et al., 2018) The very topic of many studies – notably emergency dispatch centers (Martin et al., 1997; Pettersson et al., 2004) and crisis coordination (Purohit et al., 2014) – may support the idea that control rooms deal with manifold contingencies and high workloads and are hence not routine workplaces.

Indeed, some studies take one more step into the reification of these 'events': this happens when they encode the idea of there being control room events to the cooperative tools being developed (Panagiotou et al., 2016). From our perspective, however, as already, indicated the focus on events prompts a dualism: action is pigeonholed into situations that are like events and those that are non-events, whereas for us, events do not happen outside of or before other actions precisely because all action is already ongoing. Organizational studies on control rooms further support this same argument when they note that disruptions in electricity control room work are continuous (Roe and Schulman, 2008) and need to be matched with reflective and nonprogrammed practice, not by mere repetition of what has been done before. As Weick (2011) astutely notes, non-events are produced to be dynamic in control rooms. This is called sensemaking which, in our reading, is compatible with the idea of habitual beliefs. We draw on this background to develop empirical attention to habits nested with specific tools to contribute to current discussions on CSCW and its future directions.

3 Methods and materials

We utilize a field study approach, drawing from direct on-site observations and interviews, to study control room practices on-site. We gathered this on-site data to get insight into how the electricity system is produced, and technologies reconfigured as part of daily practice; how the infrastructure is incessantly upheld and performed in organizations in and through behaviors, techniques, and interactions (Heath and Luff, 2000; Roe and Schulman, 2008). With these issues in view, we studied an electricity distribution company in England in 2019 (operating over Yorkshire and North East England). The company as such was not specifically 'identified' or 'selected' from several other electricity utilities in the UK. Research permission was arranged with the company through collaborative research in a "flex project" Control Rooms of the Future, funded by the Engineering and Physical Sciences Research Council project via the Centre for Energy Systems Integration (CESI). No identifiable barriers or issues arose with regard

to access to this field, though the two field researchers were required to negotiate their presence and explain their research goals to higher-level managers, some of whom were part of the same project while others worked in the control room settings. In practice, we were allowed to interview each worker only once and do observations during these visits. In total, 12 electricity control room operators were interviewed along with about 20 h of participant observation.

The empirical observations of two electricity distribution control rooms included interviews with key staff. Three control room shifts were observed in each distribution system complemented by interviewing of key professionals, including higher-level managers and the control room operators themselves. The interview structure stemmed from the project context and handled questions about the potential and challenges for control room integration, in response to anticipated changes in energy system management. Due to the sensitivity of the workplace and the tight security, the interview results were written down only in notebooks. We also used the notebooks for observations about control room working practices – writing down who did what, with which other persons, by utilizing which communications devices, and what they said to us or other persons.

The larger research project contained two distinct field sites – a local gas distribution network and an electricity distribution network – but in this paper, we only focus on the latter because of the several differences between gas and electricity working practices that we have documented elsewhere (Abram and Silvast, 2021). The electricity and gas companies were embarking on experimental work on future systems – including energy storage and an electrolyzer plant that can convert between gas and electricity – but these systems were not yet commissioned at the time of the study and hence remained represented only as visions and via a simulated modeling exercise. The wider study also encompassed a regulatory review. Because of our interest in working practices and habits, we focus in field studies of everyday work from our project materials (Almklov et al., 2014).

It is important to note that the studied control room in electricity distribution does not balance supply and demand but is focused on maintenance and repairs. There is not currently any significant active network management in this region of England. The conventional energy infrastructure was designed to serve what was once a significant amount of heavy industry. Much of this industry has now gone or been scaled down and there is generally an overcapacity of energy distribution infrastructure. Much of the electrical network, for example, is over-rated or has under-used assets. Large solar installations are less popular here than in the South of England, which receives greater insolation.

However, as new, large-scale offshore wind energy plant is being installed (particularly off the coast, from Hull and the North East), the geography of this infrastructure is changing. Much of the infrastructure is aging, and as assets are decommissioned, they are likely to be replaced with lower-capacity

infrastructure. Increasing demands from electric vehicles, electric-powered heating, and local generation are also likely to bring new pressures to the network. Hence, although curtailment of decentralized renewable energy is not currently an issue in this region, it is expected to become increasingly important, and it is already practiced in other regions (such as the South West), where active network management is already in use. These changing situations are an important context for our interest in technological shifts and the resulting changes in control room habits.

In sum, these materials offer a unique empirical view into the operation of highly restricted control room settings. It is true that we do not have access to video recordings, audio recordings, and long-term observations that have been typical in ethnomethodological scholarship in control rooms (Almklov et al., 2020; Arminen et al., 2014; Luff and Heath, 2019; Pettersson et al., 2004). This limitation lends weight to calls for more studies using detailed conventional methods in the future. Our materials and methods offer nonetheless a sound fit with the research task at hand: we aim to vindicate a general framework synthesized from existing concepts and control room literature, that of control room habits and their interruptions, and show its usefulness in an empirical study of managing the electricity distribution. At the same time, our on-site research focusing on everyday control room work offers an antidote to polarizing statements and grand diagnoses of the social changes that energy systems have faced.

4 Results and discussion

4.1 Against grand diagnoses of current infrastructures

We have noted that the discussion on electricity distribution control rooms – just like control room studies more generally – encounters a dilemma: the technologies and markets surrounding control rooms are changing rapidly, yet control room studies necessitate the study of these changes in concrete working situations where such changes may be more gradual, embedded in habits, and simply difficult to identify. This is also true for the discourse on advances (and risks) of digitalization and as earlier and ongoing discourse on the benefits and demerits of the markets in electricity distribution. It is not rooted deep enough in the lived reality of control rooms.

In our research, we discussed changing demands on control room operators with a managing engineer engaged in training. The engineer gave an account that was corroborated in subsequent discussions with other control room operators. Namely, the older control engineers were recruited based on their ‘field experience’, i.e., knowledge of the system and its apparatus. However, the increased use of ICT in the control room required different knowledge and skills. Current recruitment drives emphasized computing experience, and skill with computer games was

considered as evidence of an ability to multi-task, react quickly, and rapidly analyze complex situations. Hence, rather than routines that could be seen as requiring a minimum of problem-solving, the emphasis of the training was on its opposite, the continuous and quick reactions using constant problem-solving activity.

This managing engineer enacted a strong dichotomy between habituality and creativity. For him, the more experienced control room operators were bound to their habits in a Jamesian sense, in a situation where the power system itself had changed markedly. There was less emphasis on changing these social habits than on recruiting a generation of new workers that had been habitualized to computers – and even computer games – to provide useful actions in the control rooms.

Nevertheless, older control room operators had to adapt considerably to digital technologies during their careers – a finding that corresponds closely with how control room technicians in another context were retrained as "stockbrokers" when the Finnish electricity market was opened up to competition in the 1990s (Silvast, 2018). But these professional identities, recruitment strategies, and training practices are only indirectly linked to the observable control room work. In other words, they still operate at the level of rational descriptions of action rather than the action itself. Meanwhile, the grand societal shifts are experienced very differently in everyday working practices.

Market-based provision of infrastructures and digitalization often develops a strong focus on supply-demand balancing, which is supposedly improved by market relationships and information exchange (Silvast et al., 2018). There are larger-scoped demand and generation balancing control rooms, but even they are not strictly focused on the market only (Roe and Schulman, 2008). While these kinds of control rooms must address marketized power and energy trading variables, reliability and safety are still key factors in their actions and appraisals – and arguably in all control rooms where consequences affecting a large number of customers are at stake.

The control rooms we studied emphasize this role of safety and reliability and show that a vital part of the management of electricity distribution is not directly connected to supply-demand matching. These infrastructures are engaged in 'distribution' from the transmission to the supply system and are driven by safety and reliability issues, while effectively separated from energy trading considerations – at least in a region like ours, where the demand was predictable enough to not have to actively manage it at the time of the study. The more wicked problems – such as 'neoliberalism' or the perception of infrastructure consumers in economic theory – are therefore sidestepped to a degree. The control room is more important as an infrastructure 'node' than from a demand-production perspective.

The control room has a coordinating role and distributes the control that it exercises through its direct interaction with field engineers, landowners, operations managers, and so forth. In other words, the infrastructure is coordinated to be coherent in the electricity distribution control room. As one operator

described it, the control room has "an overall control function: this involves networking planning and support, which is integral to the network control room". In this task, another remarked that "safety is the paramount thing, and we follow stringent rules". What is important here is that while standard operating procedures are used frequently in this environment and most operation is proceduralized, and while ostensive routines are never enacted in practice but as performative routines (Feldman and Pentland, 2003), the workers still emphasized the ostensive routines discursively in the interviews. This is corroborated by other findings from electricity control rooms in Finland (Silvast, 2017): the procedures are not mere abstractions, but a part of how these workers talk about their work and give meaning to it.

But rules do not mean mechanical rule-following in this instance: thus, resembling the *performative* side of routines (Feldman and Pentland, 2003). This network management is not merely a routine or not merely about reacting to faults: in fact, the very distinction between routines and more active problem-solving is not meaningful, considering what these control rooms are like as a workplace. One high-level manager suggested to us that there are 20 planned outages a day to start with (planned outages are arranged to correct faults that are known beforehand). There was clearly a much large number of unplanned outages. Indeed, one control room operator remarked during a quiet moment that it is "unusual not to have alarms". The alarm – sounding like a train whistle – regularly interfered with our interviews.

This observation becomes a comment on digitalization. The control room habits showed us how digitalization and automatization should not be simply equated. Slayton's (2013) "digital utopianism" would be expressed in the idea that digital technologies bypass the need for human action and maintenance of working habits. It is true that digital technologies have replaced some working practices – notably the need for constant calculations, historically significant in the management of the electricity supply (Tympas, 2003). But habits and the need to resume them in instances of doubt remain central in the manual correction of faults and coordination of maintenance – in other words, performing the infrastructure coherently. These practices have not been replaced by "digitalization" and some of them may be strengthened by it.

This comment on automation is particularly important because it is also a first-order concept to the control room operators. As ethnomethodology tells us, not only do the social scientists use abstract concepts, but the actors studied also apply them. When prompted about changes in their job, one operator signaled "so much automation" increasingly in the last ten years. According to the operator, this means that when automation comes into play, "the operators have to step back". This automation – related to fault-solving, as explained below – is indeed also related to digital systems, hence the link between automation and digitalization is founded in this case. But this automation remained partial, not least due to

the legacy of older equipment in the distribution network, and the frequency of equipment failures including of automated systems themselves.

That being said, many types of digital systems were used for purposes other than automation, including maps, emails, and remote communications. There was a jumble of digital technologies from various historical periods mixing seamlessly: online maps with several graphical layers, emails being sent, used alongside with telemetry connecting to remote components, and built up gradually in the last 15 years. This long-time span – which in fact far exceeds working contracts in many other professions – is not unusual in electricity distribution with its heterogenous mix of infrastructure components of different ages. One operator, for instance, was amid managing the changing of oil in a transformer – a routine that needs to happen once in every 12 to 24 years and that could not easily be called automatic since it would not likely be experienced repeatedly during the career of one person. Furthermore, when the oil of the transformer – and the transformer itself – was 24 years old or more, the obduracy of the electrical infrastructure became an aspect of the working habits.

In summary, it would be hard to discern any single digital 'revolution' in the control room space, since so many different digitalizations in the plural meshed into the work. Digital technologies were all-pervasive as they arguably have been in grid management since the 1950s (Cohn, 2015). This argument is different from the notion of co-existing computerized tools with other tools (such as paper maps) (Pettersson et al., 2004), since the very digitalization is not one single entity.

4.2 The role of working routines

In terms of habits and their interruptions, organizational studies have stressed a vital argument on control rooms that is however easy to misread. This is that a significant part of control room work is ex-temporized (Schulman et al., 2004; Roe and Schulman, 2008). As Schulman et al. (2004, p. 25) observe, a high degree of "inventiveness is often in evidence". It is perhaps compelling to read this as a vision of wholly decentralized work where all control rooms are inventing the rules, and the social order is performed anew every time in each action. But the organizational studies go further than this: control rooms are not only or even mainly about performing without preparation. Inventiveness is needed in very specific conditions when working situations have become volatile and reactions need to be just in time. In fact, there are several conditions in control rooms where inventing work is not necessary and might even be against the rules. Our findings showed this considering the importance of working routines.

We distinguished between practices, habits, and routines in our conceptualization. Practices become habits and habits eventually become performative routines through repeated rehearsal. As a result, they may take on the appearance of mere well-structured responses drawing on what has been done – but are based in carefully structured safety practices.

Various routines play a central, more general role than improvisation in the control rooms we studied. This can be interpreted by ethnomethodology and versions of pragmatism (Kilpinen, 2000): much of everyday work must be taken for granted for habits to function. But in a setting, such as an infrastructure control room, routines are not mere manners or repeated human actions but are intertwined with working tools instead, and the working tools are created to serve certain governing regulations and standards (Almklov et al., 2014).

An example in the UK is the duration of a power interruption, where the mark of 3 min plays a major role in the regulatory instructions and guidance.[3] An interruption of service when it lasts more than 3 min has distinct impacts and framings in terms such as liability, reporting, and compensation. In our observations, we saw this 3-minute mark not only guiding the working routines but being coded directly in the fault-solving software that the operators used, called APRS, short for Automatic Power Restoration System. The operators we spoke to were not ambivalent or uncertain about this automation: they saw it as a useful addition to their work. One of them remarked that in the APRS one "lets the system do some things". The system had been coded to solve in average 70% of faults in less than 3 min. The operator would take a step back and observe what is happening, however, some manual switching was still required. He explained: "I can see what is happening when it is happening, when it works it is superb".

We saw in our observations how the routines were encoded in folders that contained specifications of working and flow diagrams of activities that described the working processes. These procedures themselves led all the way to the regulatory codes and even the license conditions of the distribution company, and trainee control engineers were examined on their knowledge (and internalization) of these codes and procedures. But they also had to be performed by the habits and the creative problem-solving of the workers to become effective in everyday work.

4.3 The role of ongoing problem-solving in the making of the infrastructure

If improvisation and inventive working practices are not feasible in a highly routinized workplace, then what role does unprogrammed problem-solving have in control room work of managing the electricity distribution? Classic work on organizational routines dedicated considerable attention to solving this issue. March and Simon (1958, pp. 185–86) argued that daily routines tend to curb planning, and in every case, highly programmed tasks seem to dominate over unprogrammed tasks in organizations. This leads them to ask: "How, then, does unprogrammed activity ever take place"? (p. 185). Their solution was two-fold: either resources must be directed to nonprogrammed activity (such as by the creation of planning units that

[3] See: Ofgem's "RIIO-ED1 regulatory instructions and guidance: Annex F – Interruptions" in https://www.ofgem.gov.uk/sites/default/files/docs/2015/06/annex_f_interruptions_0.pdf.

are not linked to day-to-day tasks in organizations) or there has to be enforced deadlines that cannot be pragmatically reached without using unprogrammed activity.

The control rooms in this field study rise to this situation in an empirically nuanced manner and the theme of habits and resuming them speaks to this theme directly. Or as recent organizational studies call it, sensemaking happens continuously to solve both programmed and unprogrammed tasks (Weick, 2011).

The findings below also become an important addition to be made to the theme of this issue on the decentralization of work and distributed workplaces. The control room does distribute but does not wholly decentralize operations. The control room brings together human actors and maintains a 'situational picture'. This 'situational picture' involves both protocols and human actors' understanding of them. This is an expression of ongoing sensemaking, or to use pragmatist terms, the resuming of habits is done by day-to-day teamwork.

The shared performing of situational pictures and ensuring that habits were effective was evident when observing the control room phone calls, several received during our observations. During phone calls, control room operators and field engineers work to a script, calling and repeating details to ensure beyond doubt that they understand one another. The risk of electric shock if a control operator disconnected the wrong part of the distribution network is significant, so protocols for communication are designed to ensure that both parties to a phone conversation are clear about exactly which part of the equipment they are referring to. In one phone call, the field engineer at the other end first spoke several numbers out loud (according to our notes, these numbers were related to water getting into the oil of the power cable). The operator then repeats these numbers out loud. The other end gives more numbers. The operator again repeats them. He then types them in a computer interface and repeats, but the other end does not respond. In other instances, field maintenance was coordinated over the phone by short bursts of talk and terms that were typed to the screen by the control room operator to embed the shared understanding.

As in these examples, the control room work is therefore for a significant degree about understanding and human actors' own belief about what is happening at a current moment: including how long actions will take, what problem is at stake, limits needed, numbers, and specifics of works being carried out. These dispositions to act in a specific way in certain situations become a matter of checking, accountability, and even liability when errors are at stake.

It is also important to qualify that this sensemaking and belief is not the same as merely possessing information or data. Control room operators need information and data, including not only predictive maintenance predictions or the measurements of the network frequency, but also weather data. Like power generation (Silvast, 2018), electrical distribution critically depends on the weather and specifically anticipating it. One operator showed us a detailed

map of lightning strikes, including ground and air strikes. Storms were continuously being prepared for. The operators hence carried out a "daily risk assessment of the weather: focused on different areas, lightning, snow, icing, and the temperature". Also flooding risks and flash floods had to be considered for their risks to the electricity infrastructure.

Yet, this information is not adequate to form habitual beliefs, nor can the risk assessment be encoded in working routines that would practically automate the work. The beliefs are more extensive and socially shared than this information of the individuals on any particular matter: as shown readily by the weather being observed by risk assessments that could be shared within the control room team. What remains for human operators is to make sense of that data.

This turns us to another change related to the decentralization of power production rather than the work itself. While this control room was not connected to supply-demand balancing, it did experience new kinds of power flows as the result of the introduction of distributed generation, such as renewables. Hence one operator said deterministically, "everything used to be linear", indicating that the situation is growing in complexity. In particular, when power flows in both directions in the network, the information system in use is not sufficiently up-to-date and does not offer a prediction of these flows. This then created again a need for sensemaking of the power flows, demanding that control engineers go back to calculations on reactance and capacitance in the system to ensure they understood power flows and how to safely isolate parts of the network. The shift toward renewable energy, coupled with putative marketization and digitalization, does not diminish the role of human sensemaking and effective habits in the control rooms. It strengthens their role in control room work and creates the need for more scholarship of them in future studies.

5 Conclusion

We have reviewed the control room literature and its gaps, generalizing control room study within CSCW using concerns from a detailed study of electricity distribution control rooms. We have then presented our own case study on electricity distribution management that empirically deepens some of the generalizations. This inquiry led to four generalizing conclusions that point to the need for evolution in the CSCW literature in control rooms.

First, and most generally, we showed the key problems studied in CSCW and highlight aspects not yet addressed empirically and with sufficient focus on methodological questions. In particular, we highlighted how a perspective focusing on material tools in control rooms can be complemented by a focus on working habits, reflectivity, and diverse working routines, from ostensive and particularly to performative (Feldman and Pentland, 2003). That human actions and material tools blend in control room work is a well-established starting

point (Østerlie et al., 2012). We demonstrated how scholars can dig deeper into this intersection, by examining habits as mediators between organizational rules at large, technologies in use and being managed, and ongoing action.

Second, our inquiry into conventional electricity control rooms and their working habits critiques the idea that control rooms have just recently become more decentralized and distributed as workplaces. While a certain image of centralized control via control rooms persists, especially when it comes to historical visions about centralized computerized control (Liacco, 2013, 1974), the focus of this paper on control rooms as central nodes of diffuse yet highly interdependent infrastructures provides a different, multi-sited vantage point (Luff and Heath, 2019). Control rooms are distributed workplaces (Blomberg and Karasti, 2013) and the working habits mediate to other locations via specific technologies in use. In fact, most control room technologies are dependent on infrastructures that span well beyond the organization (Monteiro et al., 2013) and it is difficult to pinpoint what exactly is centralized and what decentralized in the work. Thus, we argue that instead of a decentralization or centralization thesis, control room studies would benefit from asking how the distribution can be represented by reliance on effective working habits in the control room and how its material obduracy – such as aging components in the electricity network – produces specific effects in the situational control room work.

Third, we contribute to a widened scope in CSCW and control room studies. Coordination and interaction are inherent to the focus we develop on organization, teamwork, material tools, and human sensemaking via effective and socially shared habits (Weick, 2011). As over a decade ago (Roe and Schulman, 2008) these aspects remain crucial for understanding the complex and critical control room work of managing large infrastructures and representing it adequately with a strong reliance on sensemaking on the spot. The distribution control room offered an ideal research site as it merges the material cultures of the electricity network technology with skilled practice and teamwork as social cooperation.

Fourth and finally, we align this idea of habits and routines with sensemaking as a general expression of activity in the control rooms, even creativity. Organizational routines are not enacted solely as they are codified in process descriptions, for example, but they are domesticated to the control rooms through continuous and shared sensemaking: namely, inquiries on what is currently going on and how well each control room worker and maintainer is aware of those instances. As Feldman and Pentland (2003) aptly summarized several years ago, working routines are not mere surface-level rules, but routines are action. This leads us finally to reinterpret one key finding of CSCW literature. A large body of literature has shown how control room tools and methods support work practices, but we suggest that sensemaking supports the tools and methods and that they would not function at all without this largely overlooked ‘social infrastructure’ of control room habits.

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Declarations

Conflict of interest The authors declared that they have no conflict of interest.

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